This product is part of the RAND Corporation monograph series. RAND monographs present major research findings that address the challenges facing the public and private sectors. All RAND monographs undergo rigorous peer review to ensure high standards for research quality and objectivity.

Improving the Cost Estimation of Space Systems

Past Lessons and Future Recommendations

Obaid Younossi, Mark A. Lorell, Kevin Brancato,
Cynthia R. Cook, Mel Eisman, Bernard Fox,
John C. Graser, Yool Kim, Robert S. Leonard,
Shari Lawrence Pfleeger, Jerry M. Sollinger

Prepared for the United States Air Force

RAND PROJECT AIR FORCE

The research described in this report was sponsored by the United States Air Force under Contract FA7014-06-C-0001. Further information may be obtained from the Strategic Planning Division, Directorate of Plans, Hq USAF.

Library of Congress Cataloging-in-Publication Data

Improving the cost estimation of space systems : past lessons and future recommendations / Obaid Younossi ... [et al.].
p. cm.
Includes bibliographical references.
ISBN 978-0-8330-4460-0 (pbk. : alk. paper)
1. Space surveillance—United States—Costs. 2. United States. Air Force—Procurement. 3. Global Positioning System—Costs. I. Younossi, Obaid.

UG1523.I67 2008
629.43068'1—dc22

2008027761

Cover design: Carol Earnest
Cover image: Copyright Lockheed Martin Space Systems Company

Published 2008 by the RAND Corporation
1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
4570 Fifth Avenue, Suite 600, Pittsburgh, PA 15213-2665
RAND URL: http://www.rand.org
To order RAND documents or to obtain additional information, contact
Distribution Services: Telephone: (310) 451-7002;
Fax: (310) 451-6915; Email: order@rand.org

Summary

Background

A review of the acquisition programs of the Department of Defense (DoD) and the military services shows that they have a history of cost growth. This is especially true for space systems. An analysis of the data contained in Selected Acquisition Reports (SARs) reported from the late 1960s to 2004 shows that the average total cost growth factor for completed Major Defense Acquisition Programs (MDAPs) was 46 percent. This percentage was calculated by comparing the actual final acquisition costs of a program to its cost estimates presented in the SAR published at the program's Milestone B decision (MS B)[1] when the program was approved for system development and demonstration (SDD). The same comparison at MS C—the program approval for production—reveals that cost growth had not been eliminated. In fact, it averaged about 16 percent for all MDAPs. The study also reveals a systematic bias toward underestimating the development cost for space

[1] Most DoD weapon systems acquisition programs follow guidelines set forth in U. S. Department of Defense, Department of Defense Instruction 5000.2, Subject: Operation of the Defense Acquisition System, May 12, 2003. This instruction divides the defense acquisition management process into five separate milestones, which represent key decision points; the first three are commonly referred to by their letter designations A, B, and C. MS B is the decision point to transition from technology development to system development and demonstration. For programs approved prior to 2003, we used the equivalent milestone designation.

systems; this underestimation was higher than the underestimation for other weapon system types included in the analysis.[2]

AFSPC and SMC asked PAF to examine the cost-estimating process for some existing high-visibility programs and to provide recommendations based on lessons from these programs. Moreover, RAND was asked to assess the cost-estimating requirements and capabilities of SMC cost-estimating organizations—along with their resources, tools, methods, and processes—and to recommend an improved approach to cost analysis.

The primary mechanisms PAF used to carry out its analysis were an in-depth examination of two projects selected by the Air Force, the Space Based Infrared System (SBIRS)-High and the Global Positioning System (GPS); extensive interviews with all the space System Program Offices (SPOs) at SMC; discussions with other agencies and organizations that estimate the cost of acquiring systems; a supply-and-demand analysis of cost analysis personnel workload data from SMC; and a review of academic literature on organizational structure and weapon-system acquisition documents.

Conclusions

Although the SBIRS-High program had remarkably stable requirements from 1996 through 2005, it encountered many difficulties keeping to its planned budget and schedule. Our analysis shows that the SBIRS-High program experienced high cost growth of 300 to 350 percent after MS B and that most of this growth resulted from inappropriate cost and schedule estimates made by the contractor and accepted by the government.

With respect to GPS, which was chosen because of its reputation as a well-managed program, our analyses indicate that while the pro-

---

[2] Mark Arena, Robert S. Leonard, Sheila E. Murray, and Obaid Younossi, *Historical Cost Growth of Completed Weapon System Programs*, Santa Monica, Calif.: RAND Corporation, TR-343-AF, 2006; and Obaid Younossi, Mark V. Arena, Robert S. Leonard, Charles Robert Roll, Jr., Arvind Jain, and Jerry M. Sollinger, *Is Weapon System Cost Growth Increasing?* Santa Monica, Calif.: RAND Corporation, MG-588-AF, 2006.

gram had an aggregate cost underrun, significant components of that program experienced substantial cost growth. Much of that growth stemmed from cost-estimating errors. Also worthy of note is the fact that the program requirements changed substantially.

Both programs had poor results from the portions of the contracts that were awarded under the Total System Performance Responsibility approach. Also, both programs benefited from satellites in their predecessor programs that remained operational substantially longer than anticipated. In general, both programs significantly underestimated the technical risks and their potential effect on costs.

Beyond cost-estimating errors and decisions that caused program changes, the research team identified several broad problem areas endemic to the overall SMC cost-estimating function that also contributed to inaccurate estimates. The downsizing in the space industry in the 1990s reduced the number of contractors and raised the stakes for those remaining with respect to obtaining government contracts. The dwindling contractor base fostered a sense that failure to win one of the few remaining space contracts could result in the demise of the space sector of the company, and thus contractors were tempted to underbid contracts to win them. This all occurred at a time when space programs were becoming increasingly complex. The subsequent turbulence in the space industry, with plant closings, mergers, and shifting contractor personnel from one place to another, complicated the entire process of project management.

Furthermore, the acquisition process as a whole fostered optimistic cost estimates. Institutional and budgetary factors tended to erode the objectivity of the cost-estimating process, particularly the lack of independence of the cost analysts from the program offices. Moreover, the implementation of acquisition reform also fostered optimistic estimates and eroded the government's ability to oversee contractor activities. The organizational structure and distribution of responsibilities contributed to problematic estimates, as did inadequate numbers of experienced analysts and a lack of relevant data and methods to deal with space system complexities. Limited cost, programmatic, technical, and schedule data—along with insufficient coordination among cost analysts and engineers—created problems that were exacerbated

by the lack of adequate risk-assessment processes and methods, including independent assessments of programmatic, technical, and schedule assumptions.

With respect to assessing the cost implications of technical risk, both the SBIRS-High and GPS programs lacked rigor. In part, this was due to the effects of acquisition reform described above, but it also resulted from overreliance on contractor capabilities. Technical experts focused on identifying risk in specific technologies but underestimated the risk associated with the integration effort required for a complex system. Risk assessments were not always made, and those that were sometimes lacked rigorous fact-finding to support the assessments of technical content. Furthermore, up-to-date data were lacking and were inaccurate in some instances. Also, there is evidence to suggest that some risk assessments were not entirely independent and objective, having been done by the SPO, by the prime contractor, or by contracted support personnel. Some methodological limitations, such as the selection of cost-probability distributions, may also have contributed to estimating errors. Perhaps the biggest single challenge for cost estimation in these programs was the development of credible methodologies for determining technical risk, quantifying it, and incorporating the risk assessment into the cost-estimating process to produce a credible estimate.

All of this notwithstanding, the research indicates that much cost growth falls beyond the purview of the cost-analysis profession. Costs increase for a number of reasons, some of which are avoidable and some of which cannot be avoided.

A considerable portion of the cost analysis is done by systems engineering and technical assistance (SETA) contractors, who appear to carry out much of the day-to-day work for SMC. Military personnel have excellent cost analysis and quantitative skills, but they typically rotate out after one assignment and rarely serve again in a cost-estimating position. With respect to demand for future cost analysts, if we assume that the staff can accomplish the cost-estimating tasks *more* efficiently, then the demand for cost analysis will never exceed supply. If the staff accomplishes the cost-estimating tasks *less* efficiently, then demand will exceed supply about one-quarter of the time. But assum-

ing the workforce can be freely assigned to where it is most needed, by and large, SMC had an adequately sized workforce to meet its projected demands, except for one peak period in 2007—as long as the future portfolio of SMC programs remains about the same as today in terms of size and complexity. Finally, our review of the SMC cost-analysis organization suggests that it would benefit from a different organizational structure.

Recommendations

Our specific recommendations are as follows:

Institute Independent Program Reviews

We recommend that independent teams of experts work along with cost estimators to perform independent reviews in conjunction with major program reviews and milestones. Mechanisms or processes should be developed so that cost analysts can draw on broader SMC technical expertise as resources for objective and independent technical and schedule assessments, the two key factors in credible cost estimates. We recommend that SMC's chief engineer be required to review and coordinate all programmatic, technical baseline, and schedule assumptions, as contained in the Cost Analysis Requirements Description (CARD). SMC must have long-term organizational accountability not only for cost estimates, but also for programmatic, technical, schedule, and risk assessments. (See pp. 71–99 and 145–146.)

Place Special Emphasis on Technical Risk Assessment

Good cost estimates hinge on accurate technical inputs. Independent, rigorous formal technical risk assessments are needed to support all cost estimates and should be routinely updated. All cost and technical risk assessments should be cross-checked using alternative methodologies (e.g., historical analogies compared with parametric analyses). The quality of the inputs to the technical assessments should be improved by collecting and making available more relevant data and increasing visibility into contractor's capabilities. The level of technical expertise

and the communications among technical, program, and cost experts should be enhanced. (See pp. 45–69.)

Adopt a Hybrid Cost Organizational Structure for SMC

A hybrid structure, which includes the strengths of both centralized and decentralized organizations, has the most potential benefits and the fewest limitations. In particular, increasing the independence of the analysts performing major cost estimates will improve the reliability of the estimates and SMC's reputation as an organization whose cost numbers can be trusted. This change will require significant support from senior SMC leadership, as we discuss below. (See pp. 127–139.)

Realign and Strengthen the Future Financial Management (FM) Organization by Reassigning Cost-Estimating Tasks

We recommend that the cost tasks be divided between cost staff in the comptroller organization and the program offices. Cost-estimating tasks should be done within the SPO when the focus is on program execution, where changing priorities or rapid responses are common, for functions required to manage the day-to-day activities of the program, where the official position for effective interaction with SPO personnel is needed and where processes are unique to the program. The comptroller's cost staff should perform the tasks when independent analysis is a priority, experienced government leadership is required, economies of scale exist, flexibility in assignments is desired, skill sets and tasks fall outside the SPO mission, and workload and priorities are generally predictable. (See pp. 128–130 and 140–141.)

Require Major Estimates to Be Led by Experienced and Qualified Government Analysts

Contractor support staff should not lead major cost estimates. However, contractor support plays an important role in data collection, building cost models, documenting the results, and other technical assistance. SMC and Air Force human resources organizations will need to support the new staffing approach. The current approach to hiring, personnel assignments, civil service grade structure, and military force development regulations may need to be reassessed to attract

and retain competent cost analysts in SMC. Furthermore, we note that a few experienced analysts can be more effective than many inexperienced ones. (See pp. 130 and 138–141.)

Implement Best Practices from Other Cost Organizations

Our team met with various organizations performing cost analysis and collected best practices. Interviewees overwhelmingly agreed that sound initial estimates are critical and should be appropriately resourced. Other widely supported best practices consist of

- including analysts with technical/engineering, financial/business management, economics, mathematics, and statistics backgrounds in cost-estimating teams
- updating annual program cost and risk estimates
- keeping a track record of each estimate
- reviewing and archiving all major estimates
- emphasizing monthly Earned Value Management analysis as a management tool. (See pp. 131–133 and 159–168.)

Standardize Cost Data Collection and Improve Current Databases

In addition to historical cost information, the SMC Comptroller's cost staff should also collect historical programmatic, technical, and schedule data and archive it for future use. We encourage regular data exchanges with internal Air Force organizations, such as the Air Force Cost Analysis Agency, and external organizations, such as the National Reconnaissance Office and NASA, as a critical aspect of this data collection. (See pp. 193–202.)